

MICROBIAL ALTERATION OF MASKELYNITE: IMPLICATIONS FOR ALH 84001. K. A. Van Cleave¹, L. L. Robbins², and M. S. Bell³ ¹University of South Florida Geology Dept., Tampa, FL (kvancelea@luna.cas.usf.edu), ²U.S. Geological Survey, Center for Coastal Geology, St. Petersburg, FL (lrobbins@usgs.gov), ³NASA JSC, Houston, TX 77058 (mary.s.bell@jsc.nasa.gov).

Introduction: Since the initial discovery of carbonates in the Martian meteorite ALH 84001, extensive research has been devoted to determining whether these mineral assemblages have any implications for past life on Mars. Recently, Pb-Pb dating techniques indicate that the carbonates may have formed approximately 3.95 Ga [1], during a period when the conditions on Mars were characterized by abundant water and warm temperatures [2]. Carbonates with higher $\delta^{18}\text{O}$ values may have formed at temperatures between 70 and 90° C [3]. McKay et al. (1996) [4] have suggested that the rosette-shaped carbonates present in the meteorite may contain possible evidence of ancient microbial life forms. The time period and conditions under which the carbonates in ALH 84001 formed correspond to the time when microorganisms first appeared and developed on Earth [5].

Many microorganisms are capable of precipitating mineral assemblages by enhancing nucleation in a saturated solution and by changing the geochemistry of the hydrodynamic boundary layer surrounding their exteriors [6]. Preliminary data suggests that Fe and Mg-rich carbonates, which are present in ALH 84001 maskelynite, may have been biogenically precipitated.

Maskelynite in ALH 84001: Carbonates in ALH 84001 have been shown to be enriched in iron and magnesium [8]. Textural observations imply that carbonates in the Martian meteorite selectively replaced feldspathic glass (maskelynite) during their formation [7]. It has been suggested [1] that the Fe and Mg-rich carbonates may have been derived from a source other than the maskelynite. Microbial alteration of silicate glass has been observed in nature and under controlled conditions [9]. Fisk et al. (1999) [9] have suggested that microorganisms use silicate glass as a source of phosphorous or iron, and possibly as a metabolic substrate.

Past experiments performed by Robbins et al. (1999) [8] have shown that the anaerobic, chemolitho-heterotrophic, sulfate-reducing bacterium *Desulfovibrio desulfuricans* is capable of precipitating carbonate mineral assemblages

and depositing biofilms onto the surface of orthopyroxene samples. We propose that carbonates in ALH 84001 associated with maskelynite may have been biogenically precipitated during microbial alteration of the silicate glass.

Methods: Two 50 mg chips of maskelynite were obtained from the Manicouagan impact crater in central Quebec, Canada. The maskelynite samples were immersed in an HCl bath and washed exhaustively with deionized water. The chips were then placed in two 50 ml flasks containing microbial media. One flask was inoculated with colonies of the anaerobic, sulfate-reducing bacterium *Desulfovibrio desulfuricans*. Both flasks were equipped with sponge stoppers and placed in a glass dessicator containing a $\text{H}_2 + \text{CO}_2$ gas pack with a palladium catalyst. The glass dessicator was then evacuated and placed in an incubator set at a temperature of 35°C. The samples were incubated for a period of 14 days. The maskelynite pieces were then removed from solution and sputter coated with gold-palladium. The samples were then analyzed using energy dispersive X-ray analysis (EDX) and photographed using a Hitachi S-3500N scanning electron microscope (SEM).

Results: Distinct regions of the maskelynite sample exposed to the sulfate-reducing bacteria [Fig. 1] showed salient dissolution features and numerous borings approximately 2 μm in diameter. Areas where these alteration features were located showed the presence of bacteria and possible precipitation. [Fig. 2] The resolution of the EDX was not sufficient in identifying the composition of these precipitates. The control sample of maskelynite not exposed to the bacteria [Fig. 3] showed none of the dissolution or boring features present in the exposed sample.

Discussion: Electron microprobe analysis of the Manicouagan maskelynite, performed by Arndt et al. (1982) [10], revealed that the glass contained potassium (0.5%), silica (53.0%), and calcium (11.7%), which are utilized by microbes for metabolic activities. Electron microprobe data also revealed that the maskelynite contained

only minor amounts of Fe (0.2%) and no Mg [10]. The dissolution and boring of the plagioclase glass by *Desulfovibrio desulfuricans* demonstrated that these microorganisms attack silicate glasses that are not necessarily Fe and Mg-enriched. Sulfate-reducing bacteria incorporate iron into proteins such as ferredoxins, cytochromes of the c_3 group, and nitrogenase [11]. The *Desulfovibrio desulfuricans* bacteria may have attacked the maskelynite in order to obtain the trace amounts of iron present within the glass. Future experiments will involve the enhancement of precipitate production and the analysis of microbially-induced precipitates associated with the dissolution features to determine if they contain Fe utilized by bacteria. The establishment of microbially-induced Fe-rich carbonates associated with maskelynite may

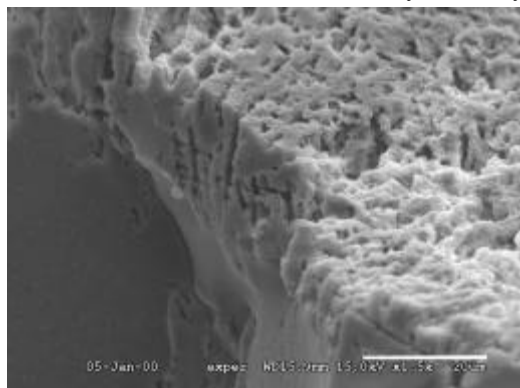


Figure 1. Maskelynite sample exposed to *Desulfovibrio desulfuricans*. SEM image, scale bar 20 μm. Sample shows salient dissolution features and numerous bore holes.

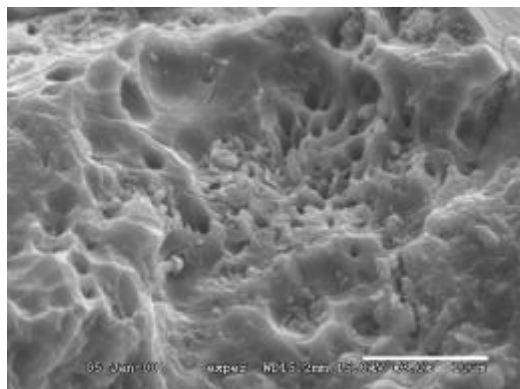


Figure 2. Maskelynite sample exposed to sulfate-reducing bacteria. SEM image, scale bar 10 μm. Yellow arrows point to bore holes approximately 2 μm in diameter. White arrows point to *Desulfovibrio desulfuricans* bacteria. Red arrows show the presence of possible precipitates.

demonstrate that Fe in ALH 84001 carbonates associated with maskelynite was originally present as trace metals within the plagioclase glass. Ultimately, we hope to produce carbonate-maskelynite associations similar to those found in ALH 84001.

References: [1] Borg et al. (1999) *LPSC XXX* #1430. [2] P. Warren (1998), *JGR*, 103, E7, 16759-16773. [3] J.M. Saxton et al. (1997), *Earth and Planetary Science Letters* 160, 811-822. [4] McKay et al. (1996) *Science* 273, 924. [5] Gibson et al. (1999) *LPSC XXX* #1174. [6] Schultze-Lam et al. (1997), *Chemical Geology* 132, 171-181. [7] Gleason et al. (1997) *GCA* 61, 3503. [8] Robbins et al. (1999) *LPSC XXX* #1464. [9] Fisk and Giovannoni (1999) *LPSC XXX*. [10] J. Arndt et al. (1982), *Phys. Chem. Minerals* 8, 230-235. [11] K.A. Perry (1995), *Georesources and Geotechnology* 13, 33-39.

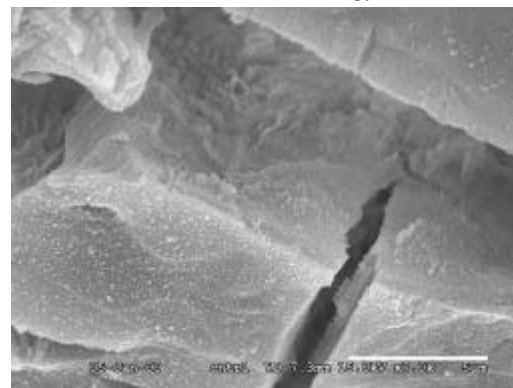


Figure 3. Control maskelynite sample, not exposed to bacteria. SEM image, scale bar 5 μm. Sample shows none of the alteration features present in Figure 1.